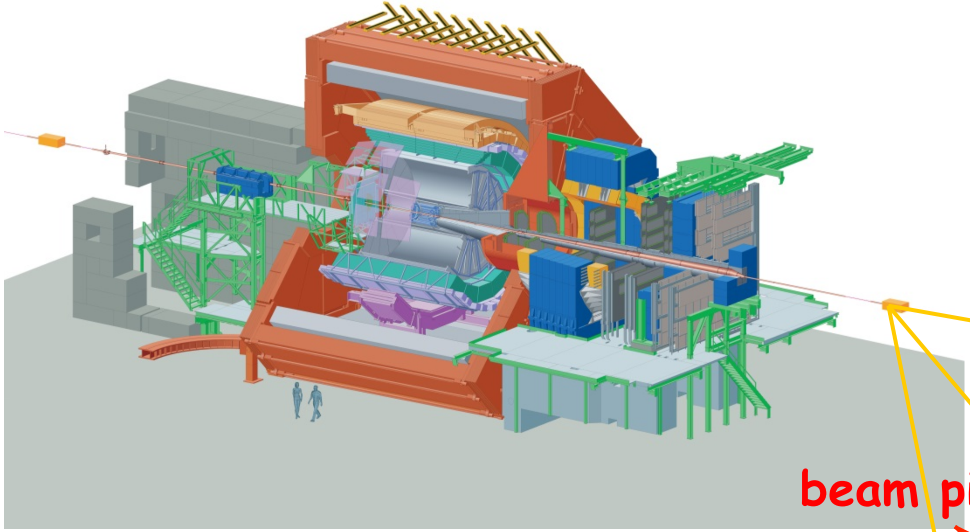
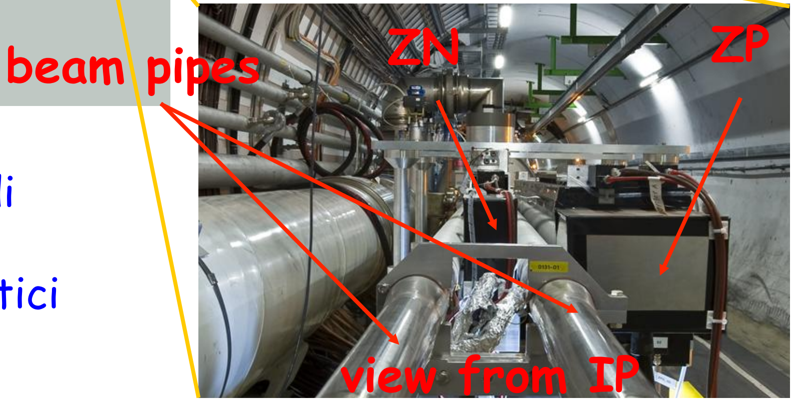
ALICE/ZDC



Progetto 100% INFN
Sezione INFN Cagliari
Sezione INFN Torino
(istituti di Alessandria e Torino)



Il progetto ZDC consiste in 2 coppie di calorimetri adronici (112.5 m da IP2) e una coppia di calorimetri elettromagnetici (7.5 m da IP2).

ZDC in Xe-Xe

October 12-13th 2017

ZDC in PHYSICS_1 (LHC17n)

ALICE agreed with LHC a low crossing angle in order to get suitable running conditions for the ZDC -> no interference between ZDC and the LHC collimators.

L3/Dip +/+ , Y_{vertex} = -2mm , BRAN conversion targets OUT

crossing angle (HALF)= +135(external) - 75(internal) = +60 μrad

ZNs as trigger detector

Discriminator thresholds well below the 1n peak.

- (ZNA or ZNC) corresponding to a σ = 106,264 b (from Pshenichnov, RELDIS)

σ = 2*singleEMDCrossSection – mutualEMDCrossSection + hadronicCrossSection = (2*50,603 - 0,692 + 5,75) b

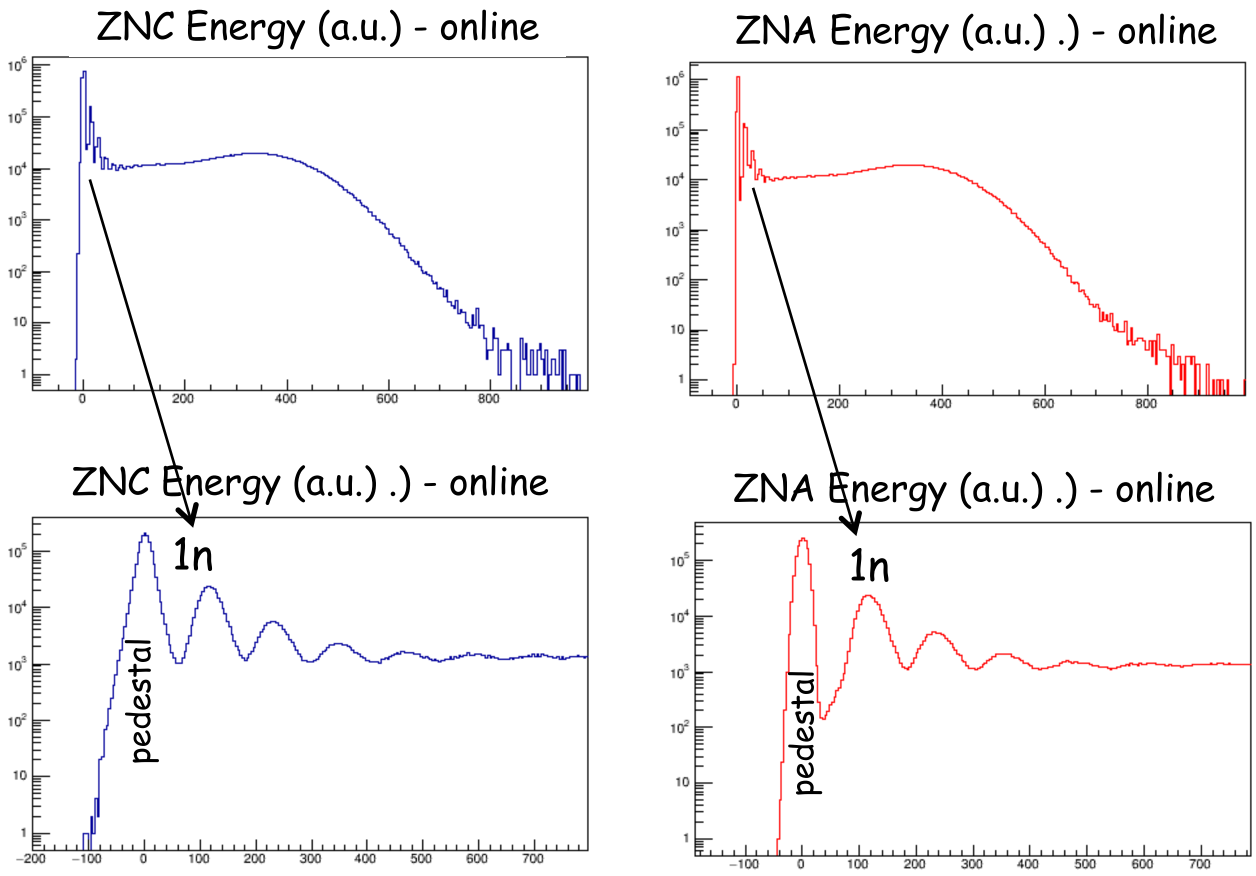
Tag essentially neutrons emitted in EMD interactions -> **C1ZED**

- (ZNA and ZNC) corresponding to a σ = 6,442 b (from Pshenichnov, RELDIS)

σ = mutualEMDCrossSection + hadronicCrossSection = (0,692 + 5,75) b

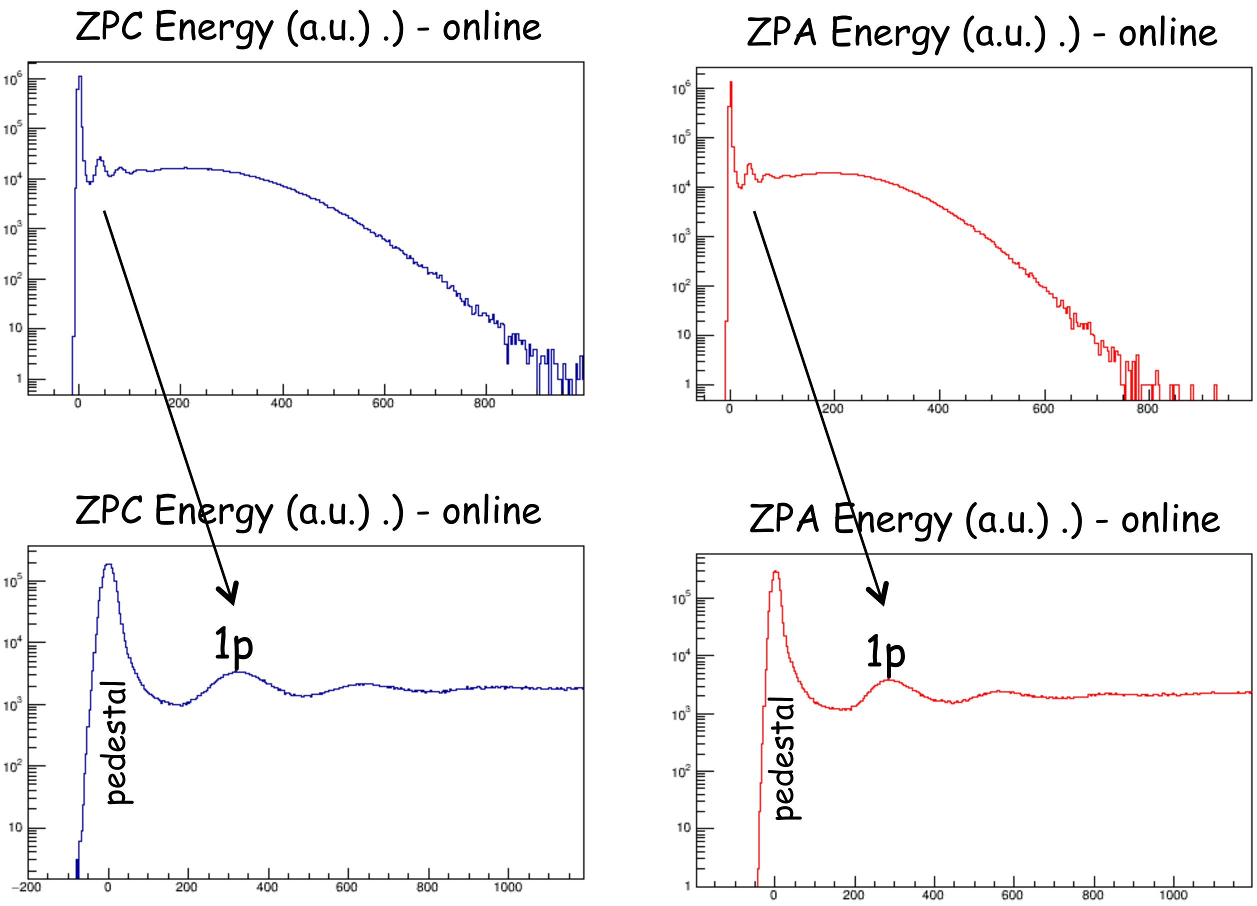
Tag essentially neutrons emitted in hadronic int. -> used to validate CINT7 -> **CINT7ZAC**

ZDC in Xe-Xe



E_{1n} = 2.721 TeV

ZDC in Xe-Xe



E_{1p} = 2.721 TeV

ZDC in p-p 6,5 TeV

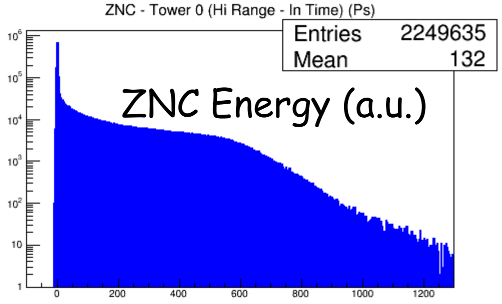
June 29th - July 1st 2018

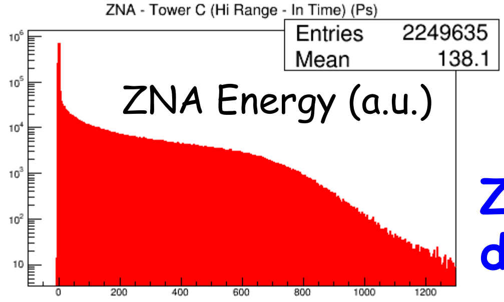
ZDC in PHYSICS_1 during LHCb, ATLAS and CMS vdM scan (LHC18i)

ALICE agreed with LHC a low crossing angle in order to get suitable running conditions for the ZDC -> no interference between ZDC and the LHC collimators.

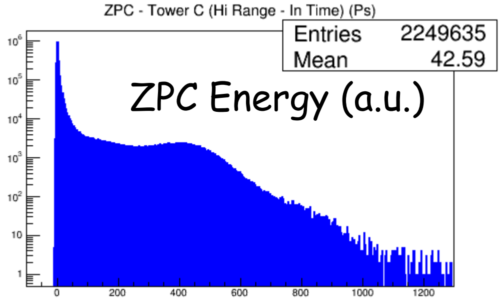
L3/Dip +/+ , Y_{vertex} = -1mm instead of usual -2mm , BRAN conversion targets OUT

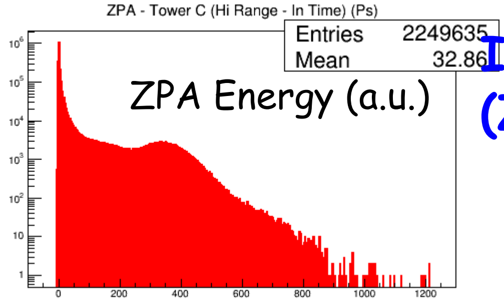
crossing angle (HALF)= +145(external) - 75(internal) = +70 μrad





Run 288864





ZDC fully operational during vdM scan period.

It provided the C1ZED (ZNA or ZNC) trigger.

ZDC – attivita' 2018/2019

2018

Issue concerning the movement of the ZPA platform solved.
New ZPA masterdrive installed in the LHC service tunnel UA23 during an access the 17th May 2018.
ZDC switched on during pp vdM scan in June 2018.
ZDC switched off and in garage position for the bulk of the pp data taking.
Of course ZDC will resume operation before and during the PbPb run in November 2018.

2019

Replacement of common PMTs of hadron calorimeters.
Replacement of servo controls for the 4 ZDC platforms (the present ones are discontinued) and subsequent commissioning.
Ordinary maintenance of the ZDC platforms.
New patch panels for HV interface of hadronic calorimeters.

Richieste ZDC 2019

M&OB ZDC 2019
11 KCHF -> 9,5 KE

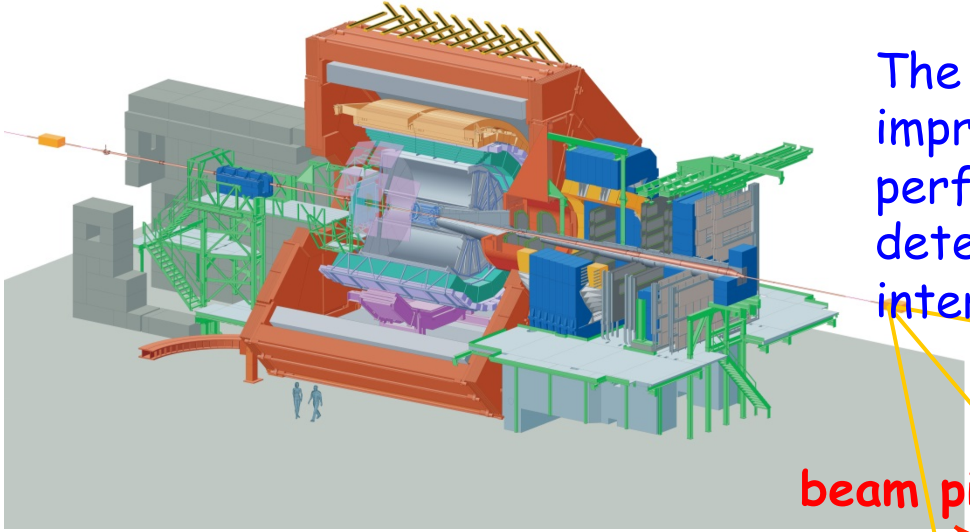
Missioni estere
Richiesta ZDC 2019 -> 12 KE
4 KE per rinnovo elettronica di controllo delle piattaforme e commissioning
4 KE per sostituzione PMT Comuni e commissioning
4 KE per decommissioning sistema di readout e installazione acquisizione standalone

Consumo
Richiesta ZDC 2019 -> 2 KE
per sviluppo di nuove basi per riduzione del ringing

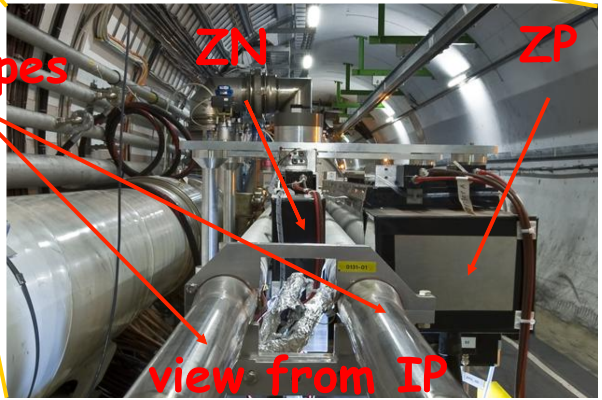
M&OB ZDC (KCHF)

Ref.	Description	2019	2020	2021	2022
A01	Mechanics		1.5	1	1
A02	Gas Systems				
A03	Cooling Systems				
A04	FEE spares			2	2
A05.1	Standard Electronics LV/HV PS				
A05.2	Standard Electronics Crates				
A05.3	Standard Electronics R/O modules			2	2
A06	Controls (DCS & DSS)				
A07	Sub-Detector spares				
A08	Areas				
A09	Communications	**1**	1	1	1
A10	Store Items		2		
A11.1	Technical Manpower @ CERN: Industrial Support				
A11.3	Technical Manpower @ CERN from Collaborating Institutes	**10**	10	10	10
Total		**11**	13	16	16

ZDC upgrade



The main target of ZDC upgrade is the improvement of the readout performance, allowing to read out the detector at 100 kHz of PbPb hadronic interactions without dead time.



TDR foresees a triggered readout.

Starting from mid-2016 investigated strategy for continuous readout.

ZDC upgrade

ZDC in continuous readout increase the physics potential in ultra peripheral collisions

In triggered mode ultra peripheral events are discarded because outside the MB trigger acceptance

In continuous readout mode EMD events will be acquired

Pb+Pb 2.7+2.7 ATeV - RUN3

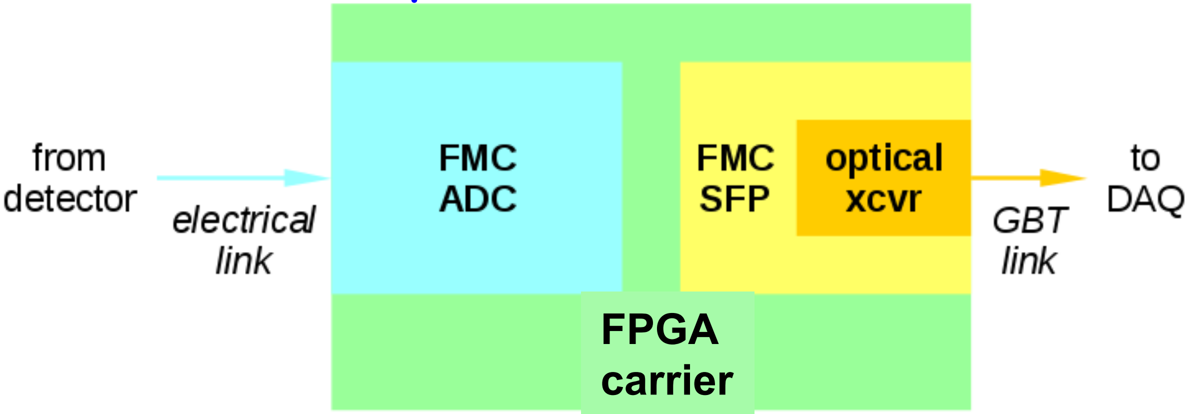
Process	σ (b)	Rate(KHz)	Affects
Hadronic	7.88	100	ALICE and all ZDC cal.
Single EMD	215	**2728**	ZNA, ZNC or both
Mutual EMD	6.21	79	ZNA and ZNC

Critical mode for the ZDC, due to high cross sections for neutron emission by electromagnetic processes

-> 100 KHz hadronic interactions with additional 2.7+2.7 MHz of electromagnetic interactions not seen from ALICE barrel

ZDC readout strategy

The ZDC readout will have to operate at 2,7+2,7 MHz without dead time, since the detector is also sensitive to EMD processes.



- FMC fast digitizer (ADC) that allow a continuous sampling of the signal waveform followed by a real time analysis on a FPGA. The portions of waveform where a signal is present are
- transferred to the DAQ through an optical link (GBT).
- 12 bits, 1 GS/s digitizer to preserve time and charge resolution
- FMC standard allow high bandwidth to FPGA and DAQ
- FPGA: data compression and waveform analysis
  - trigger processing or autotrigger; timing and signal integration

Attivita' upgrade 2017-2018

- Implementazione del firmware del digitalizz. Vadatech FMC228 su Kintex Ultrascale board
- Studio delle performance del FMC228 presentate al pre-EDR meeting a Dicembre al Cern (**https://indico.cern.ch/event/686571/**) .
- Implementazione del firmware del digitalizz. IOxOS ADC_3112 su Virtex-6 ML605 board
- Studio delle performance del ADC_3112 in corso e presentate al EDR meeting a Giugno e Luglio al Cern (**https://indico.cern.ch/event/734339/**). Dopo l'estate previsti test del FMC fornendo clock esterno.
- A Novembre e' previsto lo studio delle performance del FMC durante le collisioni Pb-Pb, usando un prototipo della catena di readout con trasmissione tramite UDP (FMC + evaluation board + readout server).
- Implementazione del link GBT tramite due evaluation boards di test e attivita' relativa al recovery e alla distribuzione del clock.
- Studio degli effetti del rumore elettronico sulla digitalizzazione, studio degli algoritmi di autotrigger, studio della ricostruzione dell'ampiezza (o carica) del segnale, studio della linearità del digitalizzatore e della stabilità del segnale fino al rate massimo di 2,7 MHz.

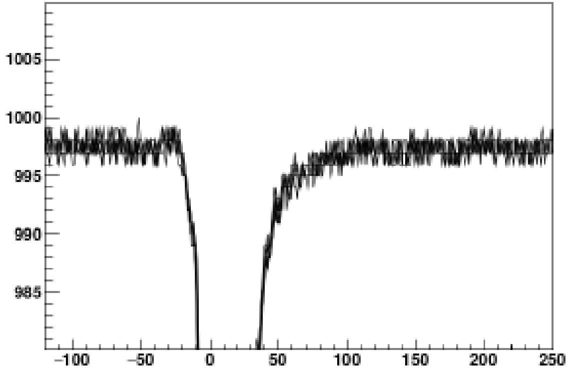
ZDC – Upgrade
FMC: Vadatech FMC228

Equipped with two ADCs AD9234, 12 bit, 1 GSps JESD204B dual ADC

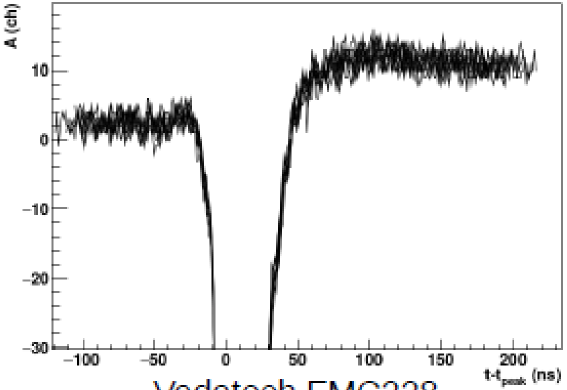
	FMC228
sample rate (GSps)	1
resolution depth (b)	12
module price (KCHF)	4,5
channel number	4
input coupling	*AC*
input voltage (Vpp)	1,34 V
enob ~1GHz (b)	10

The digitizer was advertised as DC coupled but in reality is AC coupled.

Vadatech FMC228 vs true DC digitizer CAEN-V1751

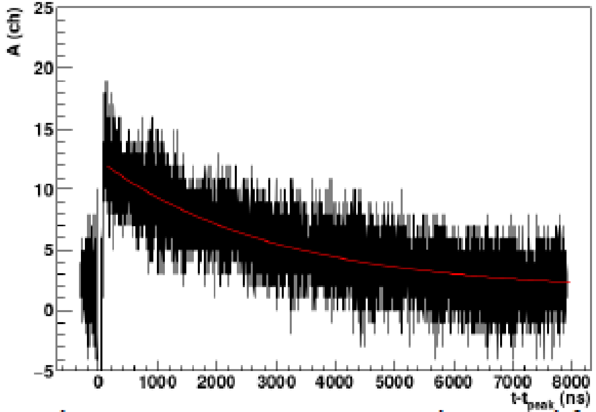


CAEN-V1751



Vadatech FMC228

For FMC228 the baseline is not restored immediately after the signal
Amplitude of overshoot signal is ~ 1.5%

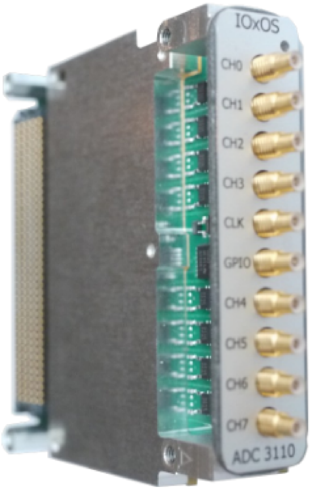


Extremely large time constant: ~ 3μs
Bouncing signal is ~ 1.5% of negative amplitude

The CAEN-V1751 cannot be used for ZDC upgrade for severe readout bandwith limitation (80MB/s)

ZDC – Upgrade
FMC: IOXOS ADC_3112

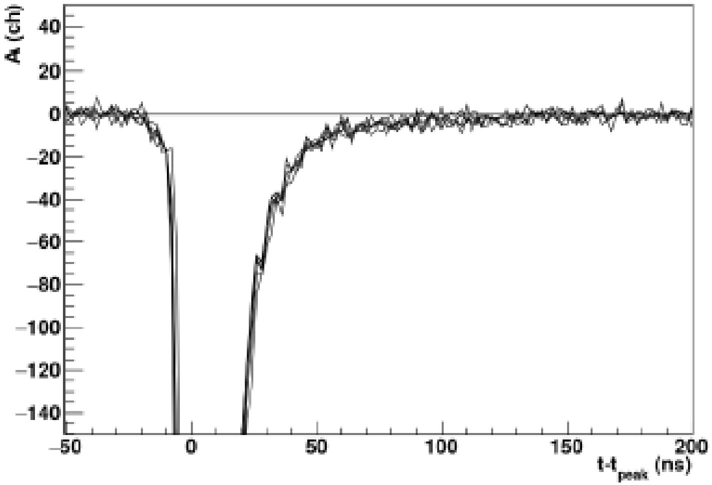
Equipped with two ADCs ADS5409, 12 bit, 900(1000) MSps



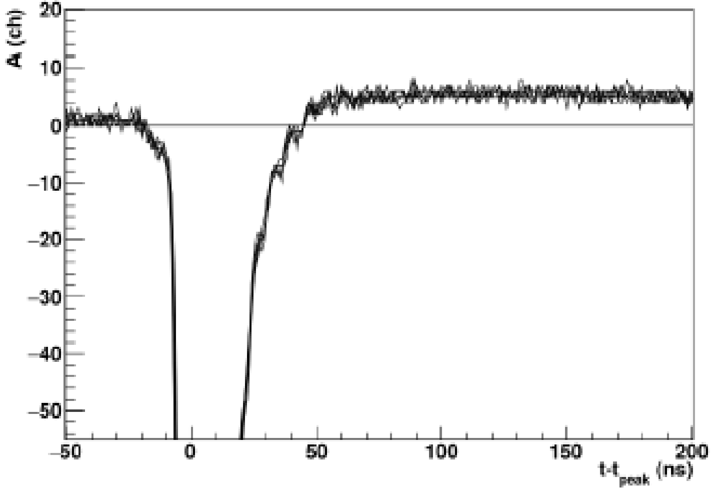
	ADC_3112
sample rate (MSps)	900 (1000)
resolution depth (b)	12
module price (KCHF)	5
channel number	4
input coupling	DC
input voltage (Vpp)	500 mV
enob ~1GHz (b)	9,8

IOxOS ADC_3112 vs Vadatech FMC228 Coupling

System tested in laboratory with ZDC PM and fast diode and at CERN with fast laser used for ZDC calibration.



IOxOS ADC_3112



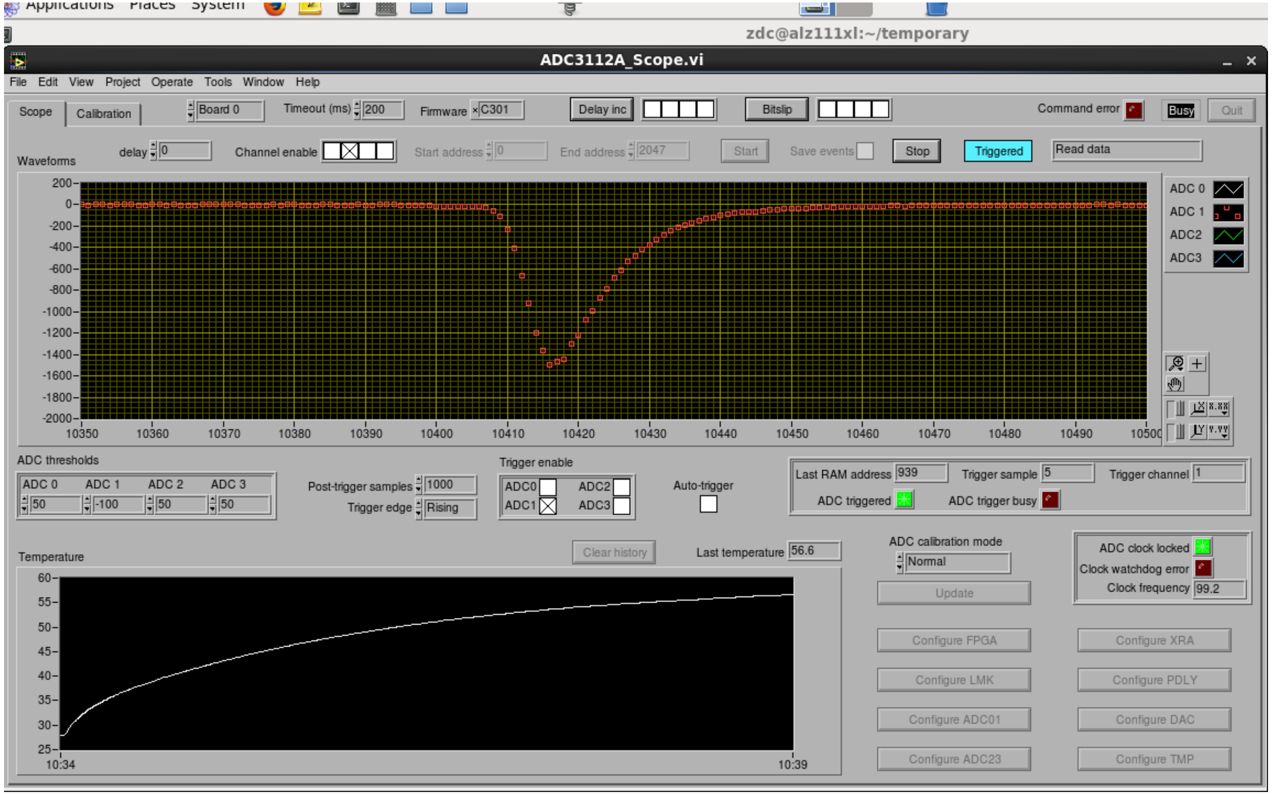
Vadatech FMC228

The IOxOS baseline is restored immediately after the signal->true DC coupling

Would allow a simpler processing of the signal w.r.t. FMC228 Vadatech

FMC: IOXOS ADC_3112

Fast diode with ZDC PM, HV=1060 V



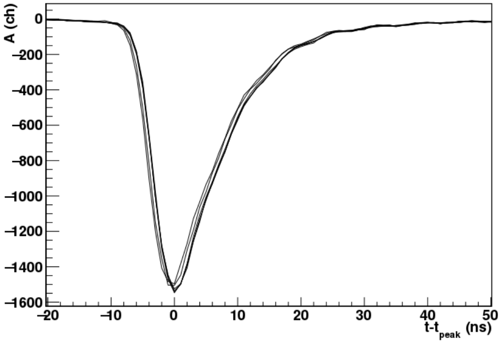
ADC_3112 digitiser readout using Virtex-6 ML605 ev. board

LabVIEW interaction with firmware via custom Gigabit Ethernet UDP protocol. Acquisition program with basic trigger logic in hardware and oscilloscope style interface.

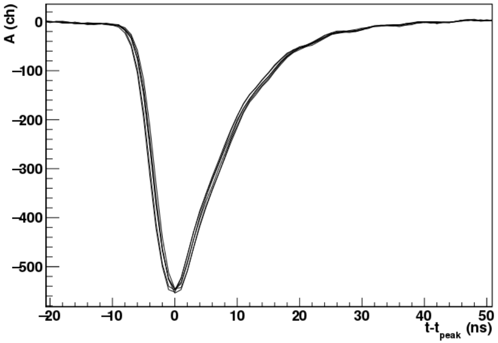
IOxOS ADC_3112 vs Vadatech FMC228

Same signal (ZDC PM with fast diode) on both digitizers at 1 GS/s

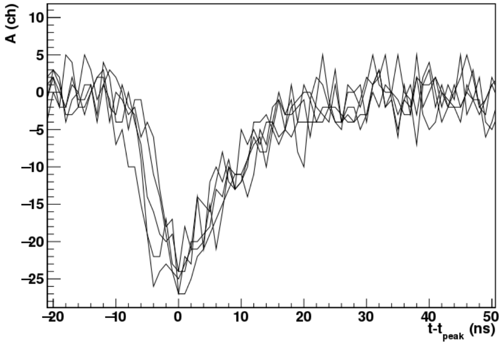
IOxOS ADC3112 (60n)



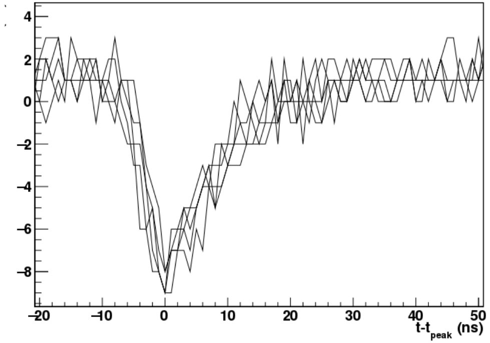
Vadatech FMC228 (60n)



IOxOS ADC3112 (1n)



Vadatech FMC228 (1n)

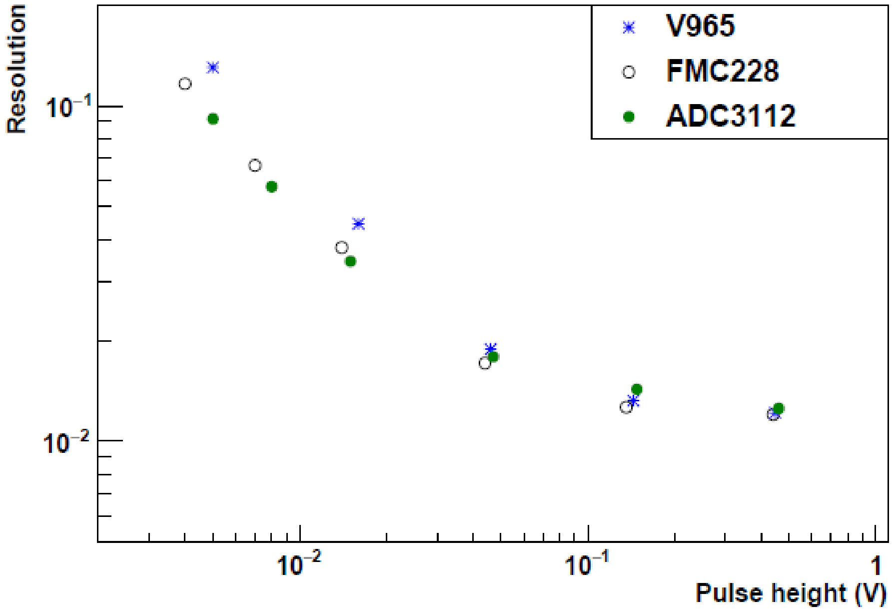


IOxOS a a bit more noisy w.r.t. Vadatech.

The noise is much lower than the 1n signal for both digitizers.

Resolution on the charge

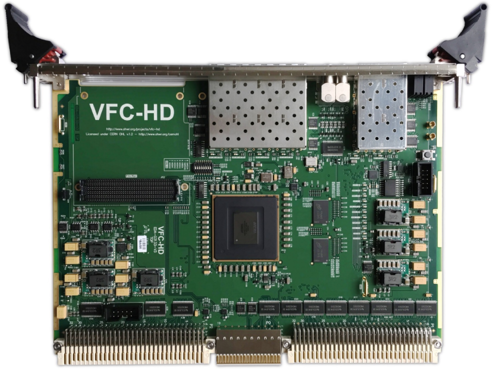
The reconstructed waveform of the digitizers has been integrated over the time of a bunch crossing (25 ns) after an optimization of the integration range w.r.t. to the time of maximum amplitude of the signal.
The results are compared with the performance of the present electronics that is based on CAEN V965 QDCs where all the signal (~60 ns) is integrated.



The new digitizers give a resolution comparable or better than the present system. The ADC3112 has slightly lower resolution for high signal amplitudes while it is comparable with the FMC228 in the lower part of the pulse dynamic range.

- **IOxOS ADC_3112 seems the best choice**
  - true DC coupling, comparable performance

ZDC – Upgrade
VFC-HD VME carrier board



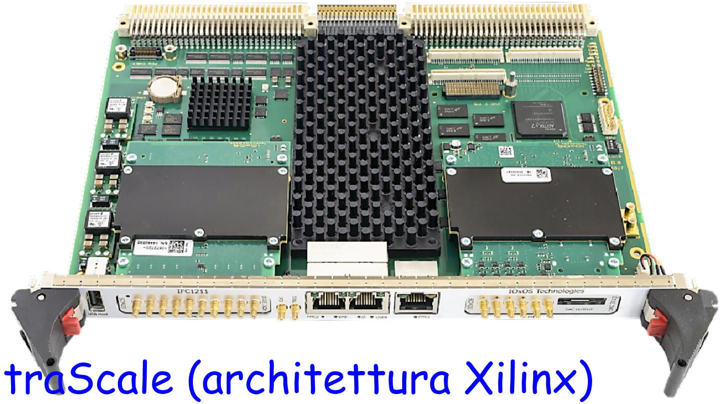
Pro

- Soluzione adottata dal gruppo BI di LHC ma con diverso FMC
- VME Carrier sviluppato sotto CERN Open Hardware Licence
    - Firmware di base fornito dal Beam Instrumentation group
- Disponibilita' di 4 optical transceivers per general purpose
- Prezzo basso (~2 KCHF)

Contro

- FPGA basata su Intel (Altera) -> non c'e' esperienza locale
- Non e' possibile trasmissione dati con RX recovered clock (no circuito di jitter cleaning)

ZDC – Upgrade
IOxOS IFC_1211 VME carrier board



Pro
- FPGA basata su Kintex UltraScale (architettura Xilinx)
- Distribuzione del clock di campionamento da pannello
- Sistema molto flessibile con potente processore
- Manutenzione per ~10 anni

Contro
- Connessione tra Ethernet e FPGA attraverso il processore con un protocollo PCIExpress
- 2 slot, di cui 1 occupata dal FMC che si interfaccia con il GBT per uscita ottica
- Prezzo elevato (7 KCHF)

Cabling

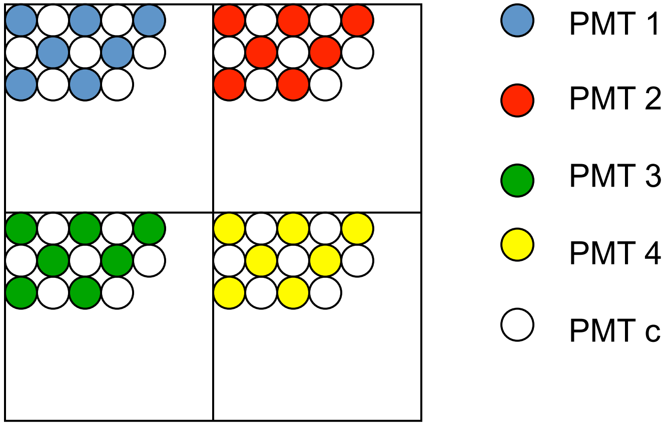
8 FMCs, 8x2 or 8x3 optical links, 22 channels

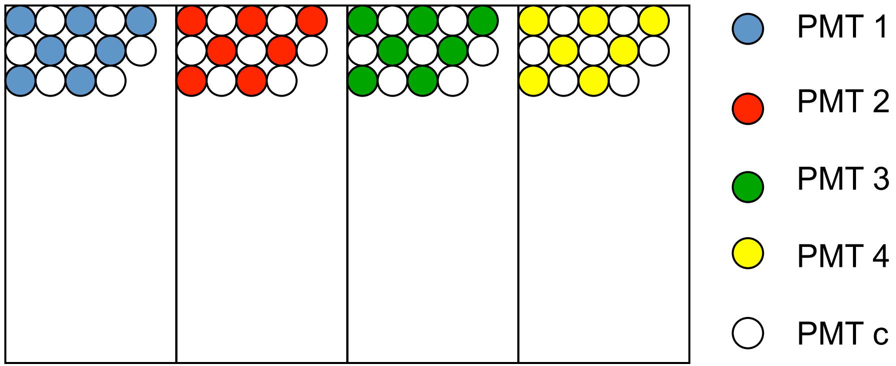
0	1	2	3
ZNA TC	ZNA TC (only trigger)	ZNC TC	ZNC TC (only trigger)
ZNA SUM (no readout)	ZNA SUM	ZNC SUM (no readout)	ZNC SUM
ZNA T1	ZNA T3	ZNC T1	ZNC T3
ZNA T2	ZNA T4	ZNC T2	ZNC T4
4	**5**	**6**	**7**
ZPA TC (trigger)	ZPA TC (only trigger)	ZPC TC (trigger)	ZPC TC (only trigger)
ZEM1 (trigger)	ZPA SUM	ZEM2 (trigger)	ZPC SUM
ZPA T1	ZPA T3	ZPC T3	ZPC T1
ZPA T2	ZPA T4	ZPC T4	ZPC T2

- **Need to forward TC or SUM trigger to the channels that are reading the towers**
- 4 ch/board does not match very well with the granularity of the ZDC readout however
    - presence of spare copy of SUM that allow change triggering scheme in case of TC failure.

ZDC read-out segmentation

The fibers are placed at 0° **with respect to the beam axis** and come out from the rear face of the calorimeter, bringing the light to the PMTs.
One out of two fiber is sent to a photomultiplier (PMTc), while the remaining fibers are collected in bundles and sent to four different photomultipliers (PMT1 to PMT4), forming four independent towers.
The chosen PMT is the Hamamatsu R329-02, with quantum efficiency around 25%.





Attivita' upgrade nel 2019

- Integrazione del FMC sul carrier finale e studio in laboratorio delle sue performance dopo implementazione dell'algoritmo di autotrigger tunato sui dati PbPb 2018.
- Implementazione del link GBT sul carrier finale.
- Implementazione del trasferimento dei dati dal digitalizzatore alla CRU (Common Readout Card) in modalita' autotrigger.
- Definizione dell'architettura della configurazione dell'elettronica a inizio run o tramite GBT-SCA oppure con interfaccia diretta con l'ECS.
- Eventuale sviluppo di nuovi partitori per ridurre il ringing se il bunch spacing in PbPb run3 verra' ridotto da 75 ns previsti a 50 ns.

Milestones

Milestones Concordate 2018
30/6/ 2018 ZDC Upgrade: caratterizzazione digitalizzatore finale: 80%
30/12/2018 ZDC Upgrade: prova sotto fascio Pb-Pb di un prototipo della catena di readout:0%

Milestones Proposte 2019
30/6/2019 Definizione dell'architettura della configurazione dell'elettronica a inizio run
31/12/2019 Implementazione del sistema di acquisizione e trasferimento dati via GBT link per un FMC in modalita' autotrigger

Richieste upgrade ZDC 18/19 Apparati

Profilo temporale aggiornato (KE)

Apparato	2014	2015	2016	2017	2018	2019	2020	Tot(KE)	FMC+Carrier
ZDC	19	0	0	16	18,5	**100**		153,5	IOxOS

- M&OB (opzione "triggered mode") -> 163 KCHF.

Upgrade ZDC 2018-> richiesto sblocco di **18,5 kE s.j.** per acquisto 3 FMC finali ADC_3112 (4,5x3=13,5 KE) e ADC_3118 VHDL firmware (5 KE).

Richiesta upgrade ZDC 2019 -> 100 KE (32 KE + 68 KE s.j.)
32 KE per acquisto dei restanti 6 FMC (4,5x6=**27 KE**) + **2,5 KE** per LS2 optical fibers + **2,5 KE** per CRU server.
68 KE s.j. per acquisto di 8+1 carriers (**57,5 KE** se carrier IOxOS) + 8+2 FMC SFP (link ottico, **8,5 KE**) + 30 transceivers ottici (**2 KE**) **s.j. alla scelta del carrier finale.**

Richieste upgrade ZDC 2019

Missioni estere -> **Richiesta upgrade ZDC 2019 -> 16 KE**
4 KE per Contatti con esperti per sviluppo GBT e configurazione sistema CRU;
4 KE per contatti con ditta IOxOS e divisione Beam Instrumentation del Cern;
8 KE per test nuova elettronica di readout in CR4 con segnali laser

Consumo -> **Richiesta upgrade ZDC 2019 -> 5 KE**
3 KE Connettori, fibre ottiche, traslatori e adattatori di clock;
2 KE sviluppo di attenuatori per adattamento segnale all'elettronica di ingresso del digitalizzatore

BACKUP

ZDC in p-p 6,5 TeV

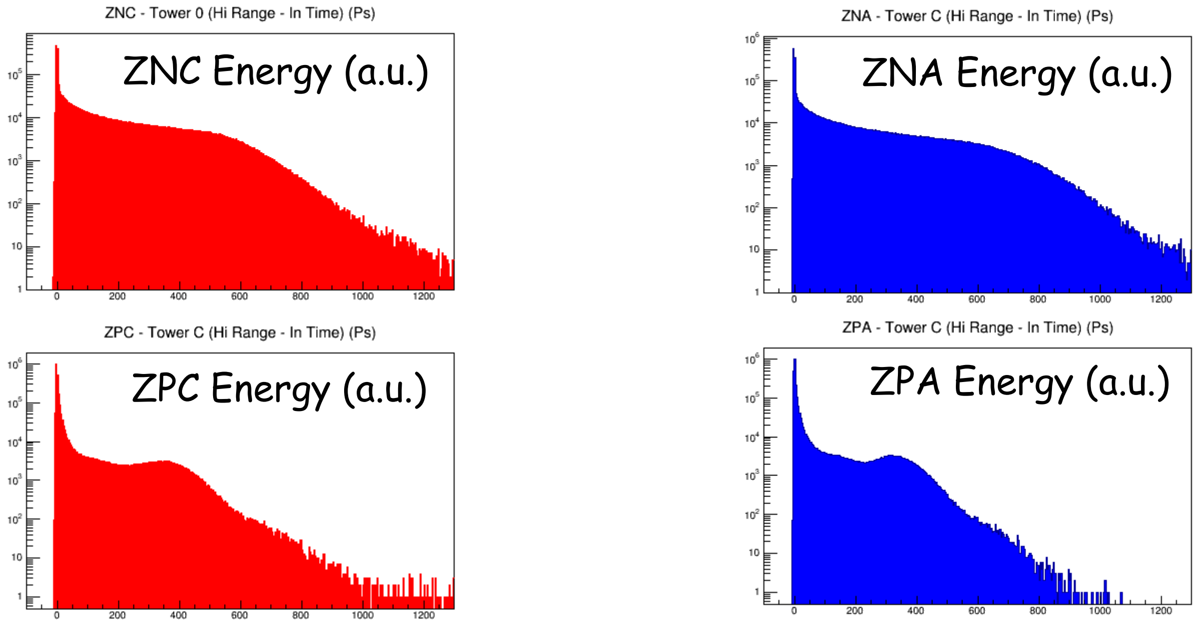
July 27-28th 2017

ZDC in PHYSICS_1 during LHCb, ATLAS and CMS vdM scan (LHC17j)

ALICE agreed with LHC a low crossing angle in order to get suitable running conditions for the ZDC -> no interference between ZDC and the LHC collimators.

L3/Dip +/+ , Y_{vertex} = -1mm instead of usual -2mm , BRAN conversion targets OUT

crossing angle (HALF)= +145(external) - 75(internal) = +70 μrad



Attivita' upgrade nel 2020

Implementazione dell'interfaccia con il sistema di trigger di ALICE
- in modalita' autotrigger lo ZDC deve comunque rispondere ai trigger di tipo heartbeat e inoltre deve passare immediatamente in modalita' triggered se richiesto

Integrazione del sistema di configurazione dell'elettronica con il DCS di ALICE
- nel sistema di test viene fatta tramite interfaccia Labview
- nel sistema finale tramite GBT-SCA oppure con interfaccia diretta con l'ECS (come in RUN1-2 se possibile)

Messa in opera della catena di readout completa:
- Local trigger unit (simula il trigger dell'esperimento)
- Common readout unit (trasmette il trigger al rivelatore e riceve i dati)
- Acquisizione (legge la common readout unit)
- FPGA di front-end (legge il flash ADC, gestisce i trigger, distribuisce il clock e spedisce i dati verso la CRU)

Installazione e test ad ALICE (CR4) del Sistema di readout completo

Continuous readout of ZDC

- Reminder: the UPC detection after LS2 will not be based on a trigger, but on the continuous readout of the relevant detectors (ITS, TPC, TOF, FIT, MCH, MID)
  - this was decided in 2014
- The requirement to have also the ZDC information was not formalised, we propose to do it now
  - Continuous readout of the ZDC seems doable but needs development and appropriate planning
- The ZDC information, while not needed to detect UPCs, may allow us to separate the various contributions of quarkonium photo-production in Pb-Pb (small-x vs high-x)

- <u>Conclusion: important to have continuous ZDC readout</u>

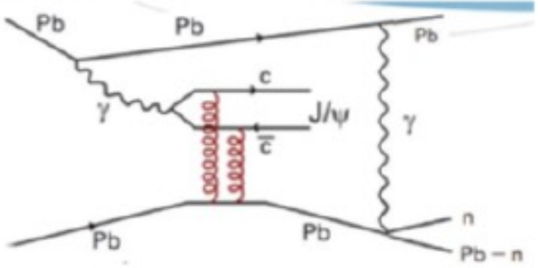
ZDC in UPC analysis

- Quarkonium photoproduction cross section is a sum of two processes

$$\frac{d\sigma_{UPC}}{dy} = n(\omega_1)\sigma_{\gamma T}(\omega_1) + n(\omega_2)\sigma_{\gamma T}(\omega_2)$$

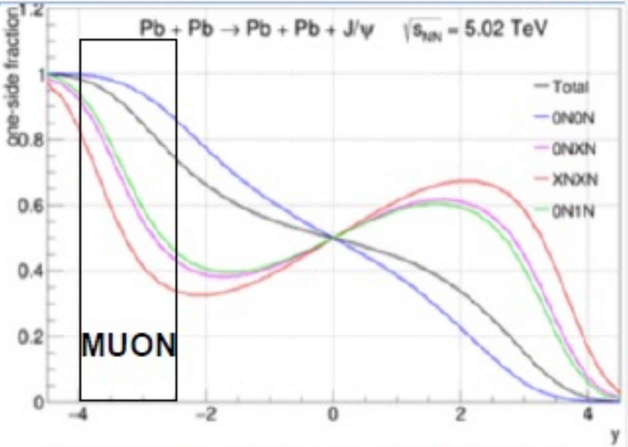
Low energy (high-x) High energy (low-x)

- Difficult to disentangle
- Forward neutron emission may allow to achieve this

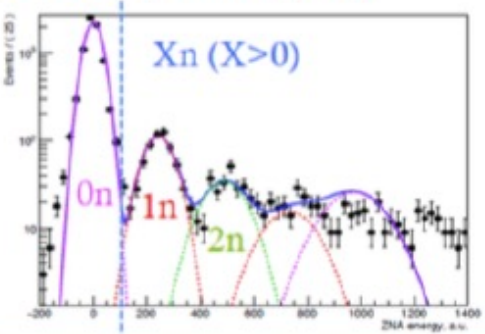


Would be important to have info from neutron ZDC for UPC events:

- continuous ZDC readout (preferred)
- continuous trigger stream from A and C side

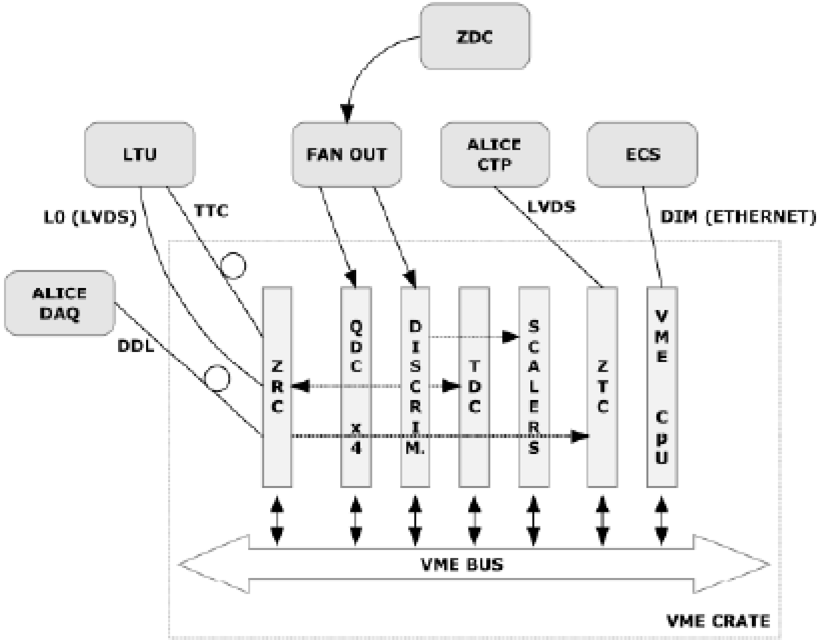


Derived from V. Guzey, EK, M. Zhalov, Phys. Rev. C 93, 055206 (2016)



Current DAQ system

The current DAQ system is:



- CAEN V965 QDCs (12 bit)
- CAEN V1290 TDCs
- CAEN V830 SCALERs (32 bit)
- Custom Differential Discriminators (precise triggering)
- NIM modules
- Custom Trigger Card (ZTC)
- Custom Readout Card (ZRC)

The present acquisition system is able to sustain a L2a rate of ~11KHz in the ZDC limited by

V965 QDCs conversion time of 10 μs → L0 of 100 kHz
VME transfer rate from V965 (D32 with BLT) → L2a of 11 KHz

10